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AGRICULTURAL ECONOMICS RESEARCH VOL. 27, NO. 1, JANUARY 1975

Input-Output Models and Technological Change: Some Explorations in Methodology

By Jitendar S. Mann

The 1963 input-output table is aggregated into a 20-sector table and additional sectors for flue-cured and burley tobacco are developed using different sources of data. Farm budget data are used to develop input vectors for flue-cured tobacco production at eight different levels of technology. Total requirements per $1 of change in final demand are calculated for each level of technology. The output multipliers for these technology levels are also calculated.

Keywords: Tobacco, technology, input-output.

The U.S. tobacco economy is faced with several potential technological innovations. An earlier ERS study outlined the complex nature of the problem and pointed the need for additional research to determine the magnitude and characteristics of the problem (*14*). The harvesting and curing of flue-cured tobacco are being mechanized at an increasing rate. A recent ERS survey of the major producing areas showed that in 1972 about 50 percent of the flue-cured tobacco was harvested with the use of tying machines, 36 percent was harvested with the use of priming aides, and about 8 percent was cured in bulk barns (*6*).

This paper was originally written to study the interaction of the various systems of technology in flue-cured tobacco production with the rest of the economy. Input-output analysis was adopted for analyzing these relationships because it takes into account the interdependence of various sectors. Several methodological issues arose in the use of the input-output table compiled by the U.S. Department of Commerce (*15*). The 85-industry table does not have enough details (*7, 9*). Although the 367-industry table is too big to be manageable, it aggregates tobacco into one industry. In the present study the main focus was on flue-cured tobacco production and this required the use of other sources of data. To study the interaction of flue-cured tobacco with other industries, alternative vectors of costs representing eight different systems of technology were developed, using data from a budget study. These eight vectors were then included in the transaction matrix, one at a time, and a solution was obtained. Although 1967 input-output data became available after the present research was completed, the paper, based on 1963 input-output tables, is being published because of its methodological significance. Moreover, the analysis of 1963 data facilitates comparison with other studies, using other approaches. The methodological issues dealt with are (1) extending an existing industry into new industries which are compatible with the original vector, (2) using farm budgets to construct input columns for different systems of technology, and (3) obtaining alternate solutions for different technologies.

Derivation of Aggregated Input-Output Table

The transaction matrix for 367 industries was aggregated into 20 industries for this study. The definitions of these industries and their relation to those of the Department of Commerce are shown in table 1. Industries 1 and 2 were derived according to procedures explained later. Industries 3, 5, 6, 10, 11, 13, and 15-18 were included as separate industries in the model because they are major providers of inputs to the tobacco production industries. The farm machinery industry was included since it occupies a central role in the analysis. Industries 7 and 8 were included as separate industries because they are major consumers of the output of the tobacco industries, and industries 4, 9, 12, and 19 because they are major suppliers of inputs to these industries. All remaining industries of the 367-industry table were aggregated together since they were not directly related to industries of interest in the analysis. The aggregated transaction flows for the 20-industry matrix are given in table 2. Each row in the table shows the distribution to each industry of the output of goods and services of a given industry. The columns show the value of each industry's use of raw materials and services. The aggregation process affected mostly industry 20; all other industries can be identified directly with the entries in the Commerce tables.[1]

[1] To be very precise adjustment should have been made for secondary production. As this was not done, there may be a slight bias in the entries for industry 20.

Table 1. Definitions of industries used in this study and by the U.S. Department of Commerce

Industry number and title used in this study		Department of Commerce industry number and title[a]	
Number	Title	Number	Title
1	Tobacco—burley	—	Not defined
2	Tobacco—flue-cured	—	Not defined
3	Agriculture—livestock	1.01-1.03	Livestock and Livestock products
4	Agriculture—crops	2.01-2.02 and 2.04-2.07	Other agricultural products[b]
5	Agricultural services	4.00	Agricultural, forestry and fishery services
6	Maintenance and repair construction	12.02	Maintenance and repair construction, all other
7	Cigarettes, cigars, etc.	15.01	Cigarettes, cigars, etc.
8	Tobacco stemming and redrying	15.02	Tobacco stemming and redrying
9	Commercial printing	26.05	Commercial printing
10	Fertilizers	27.02	Fertilizers
11	Agricultural chemicals	27.03	Agricultural chemicals, n.e.c.
12	Plastic materials and resins	28.01	Plastic materials and resins
13	Petroleum refining	31.01	Petroleum refining and related products
14	Farm machinery	44.00	Farm machinery
15	Wholesale trade	69.01	Wholesale trade
16	Retail trade	69.02	Retail trade
17	Insurance carriers	70.04	Insurance carriers
18	Real estate	71.02	Real estate
19	Advertising	73.02	Advertising
20	All others	(c)	(c)

[a]Source - (*15*).

[b]Less tobacco.

[c]Includes all industries defined by the U.S. Department of Commerce for the 1963 Input-Output Structure of the U.S. Economy which are not included in the previous 19 industries.

Derivation of Burley and Flue-Cured Tobacco Production Industries

The input-output table compiled by the Department of Commerce has only one tobacco production sector, which represents the production of all types of tobacco. Since in this study interest is focused on flue-cured tobacco production, it was necessary to define sectors which represent the production of flue-cured and burley tobacco as separate industries. The procedure followed was to divide the original aggregate tobacco sector into three subsectors: (a) burley tobacco production, (b) flue-cured tobacco production, and (c) "other" tobacco production representing all other types of tobacco. The "other" tobacco production sector was aggregated into agricultural crops (industry 4).

To disaggregate tobacco into flue-cured, burley, and other tobacco, the elements in the column of the original transaction matrix were multiplied by the ratio of the value of each type of tobacco to the total value of tobacco produced in 1963, and by adjustment factors to reflect the differences in input expenditures by types of tobacco. A further adjustment was made to make the new columns consistent with the old one.

The equation for deriving the adjusted elements may be written as

$$(1)\quad f_{it} = f_i p_t c_{it} + b_{it}$$

where:

f_{it} = modified flow element for input i of tobacco sector t.

t = 1, burley; t = 2, flue cured; and t = 3, other tobacco.

f_i = flow element for input i of the original tobacco sector. This value was taken directly from the 1963 input-output transaction matrix.

p_t = ratio of the value of type t tobacco produced to total value of tobacco (source, *13*).

c_{it} = adjustment coefficient for input i of tobacco sector t as defined below.

b_{it} = an adjustment factor, positive or negative, determined so as to satisfy the two conditions defined in equations (2) and (3).

Table 2. Interindustry transactions, 1963

(In millions of dollars at producers' prices)

Industry number and title	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. Tobacco—burley	1.1	---	---	---	4.2	---	3.4	324.9	---	---
2. Tobacco—flue-cured	---	2.7	---	---	9.2	---	7.4	712.2	---	---
3. Agriculture—livestock	30.9	79.0	4,749.8	1,709.6	191.8	---	---	---	---	---
4. Agriculture—crops	---	---	7,897.4	764.8	536.6	.3	1.0	75.7	---	---
5. Agricultural services	5.4	13.9	444.8	1,033.9	---	---	---	---	---	---
6. Maintenance and repair construction	6.3	18.4	200.1	341.9	---	4.7	4.5	2.8	7.1	6.9
7. Cigarettes, cigars, etc.	---	---	---	---	---	---	1.0	5.6	---	---
8. Tobacco, stemming & redrying	---	---	---	---	---	---	1,205.7	556.8	---	---
9. Commercial printing	---	---	---	---	---	---	57.2	---	1.7	---
10. Fertilizers	11.3	26.2	---	746.7	.6	.3	---	---	1.6	136.1
11. Agricultural chemicals	3.7	14.7	20.6	263.6	.3	.6	---	---	---	3.3
12. Plastic material & resins	---	---	---	---	---	---	88.9	.2	33.0	.3
13. Petroleum refining	5.5	41.6	169.8	906.8	3.4	116.2	1.3	.7	19.3	4.8
14. Farm machinery	.4	2.0	5.4	226.5	---	.6	---	---	---	---
15. Wholesale trade	5.5	15.2	612.4	504.2	36.2	400.0	24.8	26.5	101.2	54.4
16. Retail trade	3.4	9.5	257.5	304.8	6.0	471.6	13.2	.9	29.8	5.8
17. Insurance carriers	4.7	13.9	93.1	194.8	---	79.8	3.2	.6	8.9	2.7
18. Real estate	30.0	82.9	288.8	1,906.8	41.2	89.5	6.1	7.0	86.6	4.7
19. Advertising	---	---	1.3	13.4	---	7.3	292.8	2.2	32.9	14.6
20. All others	22.4	58.1	5,077.3	2,789.5	360.6	4,034.9	294.5	37.4	2,493.3	796.4

See note at end of table.

Continued

Table 2. Interindustry transactions, 1963--Continued

(In millions of dollars at producers' prices)

Industry number and title	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1.Tobacco-burley	---	---	---	---	---	---	---	12.8	---	14.6
2. Tobacco—flue-cured	---	---	---	---	---	---	---	28.1	---	32.0
3. Agriculture—livestock	---	---	---	---	---	---	---	162.3	---	17,570.9
4. Agriculture—crops	.1	---	---	---	---	---	---	682.2	---	9,826.9
5. Agricultural services	---	---	---	---	169.5	---	---	17.1	---	43.5
6. Maintenance and repair construction	1.0	17.5	345.2	3.3	84.0	312.8	21.3	819.4	3.4	8,735.7
7. Cigarettes, cigars, etc.	---	---	---	---	.7	---	---	4.5	---	168.1
8. Tobacco, stemming & redrying	---	---	.1	---	3.4	---	---	2.2	---	7.7
9. Commercial printing	---	---	---	---	93.1	54.5	47.5	10.9	2,081.5	2,677.9
10. Fertilizers	21.8	---	.1	.1	30.7	.1	---	29.6	---	295.6
11. Agricultural chemicals	.4	3.8	.1	.2	15.0	.1	---	13.9	---	136.0
12. Plastic material & resins	11.5	97.5	.3	---	6.9	35.0	---	15.6	---	2,661.8
13. Petroleum refining	19.5	45.5	1,413.2	6.9	762.5	583.1	32.8	488.2	7.0	6,211.3
14. Farm machinery	.1	---	---	146.5	17.6	---	---	6.4	---	407.6
15. Wholesale trade	18.9	80.3	288.1	104.5	992.7	511.8	81.9	417.6	15.6	18,507.0
16. Retail trade	1.4	9.2	33.7	13.2	457.8	196.6	92.6	678.1	23.1	6,766.7
17. Insurance carriers	.8	3.3	53.4	6.5	473.4	386.2	8.5	856.6	2.1	3,327.1
18. Real estate	1.8	22.9	413.3	12.5	1,802.9	4,613.2	608.1	2,555.4	104.8	15,443.1
19. Advertising	8.6	47.2	266.1	49.3	1,543.3	2,124.7	149.7	494.5	20.9	7,475.0
20. All others	342.4	1,856.9	12,479.9	1,592.6	9,246.5	7,647.2	6,807.4	8,106.7	9,255.5	294,977.7

For the distribution of the output of an industry, read the row for that industry. For the composition of inputs to the industry, read the column for that industry.

(2) $f_i = \sum_t f_{it}$

(3) $F_t = \sum_t f_{it}$ (See below for definition of F_t.)

This adjustment assures that the elements in the new columns sum to the elements in the old input column. The adjustment coefficients c_{ij} are derived from tobacco production budget expenditures by reweighting the expenditure items.

$$c_{it} = F_t g_t f_i p_t e_{it} / \sum_i f_i p_t e_{it}$$

where:

e_{it} = tobacco budget expenditure for i type inputs for tobacco sector t. These values were obtained from tobacco production budgets (*10*) which represent production practices on an average size farm in 1963.

g_t = an adjustment factor designed to modify the budget expenditure items to correspond to the total value of tobacco produced in 1963 defined as the ratio of average yield in the budget (*10*) to the actual yield in 1963 (*13*).

F_t = column total of tobacco sector t; defined as:

$$= \sum_i f_i p_t$$

Note that F_t is obtained simply by multiplying the total of the old tobacco column by the proportion of the value of all tobacco produced by type-p's.

Due to lack of information, all c_{it} adjustment coefficients were assumed to be 1 and all b_{it} adjustment factors 0 for the "other" tobacco sector. This sector was a catchall sector designed to aggregate the leftovers, as adequate information was not available to characterize the sector.

The new row elements were derived by multiplying the values in the old row by the ratio of the value of each type of tobacco produced to the total value of tobacco according to equation (4).

(4) $k_{tj} = k_j p_t$

where:

k_{tj} = modified flow element for new tobacco row t of sector j.

k_j = original tobacco row flow element of sector j.

p_t = proportions of the value of all type t tobacco produced in 1963.

In summary, the above procedure disaggregates the original tobacco sector so that the distribution of output of the new tobacco sectors is proportional to the value of that type of tobacco produced in 1963, but the columns are adjusted for differences in the production functions underlying the production of different types of tobacco. Also, for any row the procedure leaves the sum of the row elements of the three new tobacco sectors equal to the row element of the original tobacco sector. Moreover, for each of the new industries, the column sum of the flow elements is proportional to the value of that type of tobacco produced in 1963. The burley and flue-cured production are presented as industries 1 and 2, respectively, in table 2. The other tobacco sectors have been added to industry 4, agriculture—crops.

Other methods of setting up the columns and rows in an input-output matrix have been recommended (*5*,*11*). The technique adopted here makes the new columns and rows compatible with the original Commerce table.

Input Vectors for Flue-Cured Tobacco Production for Different Technologies

Underlying an industry's transaction flows in an input-output table is a particular system of technologies. Likewise, a particular system of technology implies a specific combination of inputs. Thus, a relationship exists between an industry's transaction flows and the combination of inputs which are used to produce the industry's output. The procedure for adjusting the transaction flows of the flue-cured tobacco production industry is to specify the combination of inputs associated with different technological systems.

Davis and Chappel (*4*) have specified in detail the combinations of inputs associated with eight different technological systems. These are:[2]

A. Conventional curing system
   (1) Hand harvesting
   (2) Automatic tying machines
   (3) Priming aide and tying machines
   (4) Priming aide
   (5) Self-propelled priming aide

B. Bulk curing system
   (6) Hand harvesting
   (7) Priming aide
   (8) Mechanical harvester

Using data from the Davis-Chappel study, adjustment factors for selected classes of inputs were estimated. These were the ratios of input expenditures for different systems of tobacco production. The flows of the flue-cured tobacco production industry in table 2 were

[2] For a detailed discussion of this classification, see (*4*). The methodology developed in this study can be used with other classifications.

then multiplied by the adjustment coefficients to obtain the transaction flows associated with the different technological systems.

The derivation of the adjustment factors is based upon the assumption that the Davis and Chappel hand system, using hand harvesting, hand curing, and a conventional curing barn, corresponds to the transaction flows of the flue-cured tobacco production (in 1963) as given in table 2. Thus, all of the adjustment factors for this system are 1. For the other technological systems the adjustment factors for a particular class of inputs (flows) will be less than 1 if the system uses less of these inputs and greater than 1 if it uses more of these inputs. That is, the adjustment factors for each technological system are derived by comparing each system with the basic hand system, hand harvesting, hand barning, and a conventional barn.

The adjustment factors for different types of transaction flows were calculated from production expenditures. For the maintenance and repair construction industry, the annual ownership costs of the tobacco curing barn were used to derive the adjustment factors. In this case only two types of barns are considered and consequently the adjustment factors take on only two values. For the petroleum refining industry, expenditures on fuels and lubricants were used to determine the adjustment factors. Since there is very little difference between technological systems in the expenditures on fuels and lubricants, all of the adjustment factors were very near 1. The adjustment factors for the farm machinery industry were relatively large and varied widely. These are based on the annual ownership costs of all equipment used, which represent repair and maintenance expenditures. Since mechanized systems use much more equipment than the hand system, and some substantially more, the adjustment factors were relatively large and varied considerably. For the insurance carriers the adjustment factors were derived from expenditures on crop, equipment, and barn insurance. Since expenditures on crop insurance dominate, these factors vary little by type of technological system.

The adjustment factors for wholesale and retail trade reflect the increased trade associated with the purchase of nonfarm inputs associated with mechanized systems. The adjustment factor is equal to the ratio of the sum of adjusted elements for other industries (that is, excluding wholesale and retail trade) to a similar sum for the hand system.

It was judged that seven purchased inputs of the flue-cured tobacco production industry are not affected by the type of technological system used in the industry. Hence, the adjustment factors for these industries are 1.

The adjustment factors were multiplied by the corresponding flows of the basic hand system to obtain adjusted transaction flows for each of the technological systems. In further analysis, it was assumed that value added is a residual which absorbs the gains and losses from the adoption of a given technological system. The adjusted transactions columns are given in table 3.

Table 3. Adjusted flue-cured tobacco column by level of technology

(Million dollars)

Industry	(1) Hand	(2) Tying	(3) Aide tying	(4) Aide	(5) S.P. aide	(6) Hand bulk	(7) Aide bulk	(8) Mecha-nized
1. Tobacco, burley								
2. Tobacco, flue-cured	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
3. Agriculture, livestock	79.0	79.0	79.0	79.0	79.0	79.0	79.0	79.0
4. Agriculture, crops								
5. Agricultural services	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9
6. Maintenance, repair, and construction	18.4	18.4	18.4	18.4	18.4	53.4	53.4	53.4
7. Cigarettes, cigars, etc.								
8. Tobacco, stemming and redrying								
9. Commercial printing								
10. Fertilizer	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.2
11. Agricultural chemicals	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
12. Plastic material and resins								
13. Petroleum refining	41.6	41.6	42.0	42.0	40.4	41.2	42.0	42.0
14. Farm machinery	2.0	10.8	13.1	5.0	13.6	2.0	10.6	60.3
15. Wholesale trade	15.2	15.7	15.8	15.4	15.8	16.7	17.2	19.8
16. Retail trade	9.5	9.8	9.9	9.6	9.9	10.5	10.7	12.4
17. Insurance	13.9	15.2	16.5	14.6	16.8	17.0	19.3	30.0
18. Real estate	82.9	82.9	82.9	82.9	82.9	82.9	82.9	82.9
19. Advertising								
20. All others	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1

Direct and Total Requirements

The matrices of direct and total (direct plus indirect) requirements were calculated using eight different input columns for flue-cured tobacco.[3] That is, each of the eight technology vectors in table 3 was used to replace column 2 in table 2 and then eight different solutions were obtained. The direct requirements show the inputs required by an industry from each of the other industries to produce $1 of its output. The total requirements matrix takes into account both the direct and indirect requirements of an industry. A matrix of total requirements shows the total requirements by each industry from each of the other industries per $1 increase in final demand. The massive amount of information in the total requirements matrices is summarized by summing the total requirements of each industry. These sums, called output multipliers, measure the sum of direct and indirect requirements from all industries needed to deliver an additional $1 of output of a particular industry to final demand (*12*). The output multipliers for eight systems of technology are given in table 4.

The output multipliers increase as we move from technology 1 (hand harvesting with conventional curing) to technology 8 (mechanized harvesting with bulk curing). For example, for flue-cured tobacco production, the multiplier is 1.86 for level 1 and 2.12 for level 8. For stemming and redrying, the multiplier is 2.77 for level 1 and 2.89 for level 8. The biggest increase is in flue-cured tobacco production (industry 2). The increase in stemming and redrying (industry 8) reflects the impact of mechanization on increased derived demand for processing. Industry 14, farm machinery, shows very little change. This needs further study at a regional level, concentrating attention on areas where tobacco is produced and processed.

[3]The standard procedure for obtaining the total requirements is discussed in (*3*) and (*8*). For a similar application see (*1*). The tables for direct and total requirements are not reproduced here.

Summary and Conclusions

The research reported in this paper was undertaken to determine the interaction of the adoption of the different systems of technology in tobacco production with the rest of the economy. It was discovered that the differences in output multipliers for different systems of technology were very small. A closer look at the data showed that tobacco is a very small sector of the U.S. economy. In 1973, 1.8 percent of cash receipts from farming in the United States were from tobacco. When working with national magnitudes, the tobacco activities, being very small fractions of the total economy, get lost in large numbers. The production, processing, and manufacturing of flue-cured tobacco are regional activities concentrated in North Carolina, South Carolina, Virginia, and Georgia. Therefore, it is recommended that further work should be done on a regional basis.

However, several other lessons about input-output analysis were learned which are worth noting. In using the 1963 input-output table for analysis of the tobacco sector, some peculiar facts were discovered. The table shows that the tobacco industry purchased inputs valued

Table 4. Output multipliers for 8 levels of technology

Industry	(1) Hand	(2) Tying	(3) Aide tying	(4) Aide	(5) S.P. aide	(6) Hand bulk	(7) Aide bulk	(8) Mecha-nized
1. Tobacco—burley	1.64067	1.64068	1.64068	1.64068	1.64068	1.64069	1.64069	1.64072
2. Tobacco—flue-cured	1.85903	1.88505	1.89510	1.86962	1.89269	1.93486	1.96466	2.11887
3. Agriculture—livestock	2.56669	2.56670	2.56670	2.56669	2.56670	2.56671	2.56672	2.56676
4. Agriculture—crops	1.95766	1.95767	1.95767	1.95767	1.95767	1.95769	1.95770	1.95775
5. Agricultural services	2.36529	2.36543	2.36548	2.36534	2.36547	2.36569	2.36586	2.36668
6. Maintenance and rep. construction	1.74927	1.74927	1.74927	1.74927	1.74927	1.74928	1.74928	1.74929
7. Cigarettes, cigar, etc.	1.98116	1.98396	1.98504	1.98230	1.98478	1.98933	1.99254	2.00914
8. Tobacco stemming & redrying	2.76777	2.77984	2.78450	2.77268	2.78338	2.80293	2.81676	2.88827
9. Commercial printing	2.03412	2.03412	2.03412	2.03412	2.03412	2.03412	2.03412	2.03414
10. Fertilizers	2.49670	2.49671	2.49671	2.49670	2.49671	2.49671	2.49671	2.49673
11. Agricultural chemicals	2.49075	2.49075	2.49076	2.49075	2.49075	2.49076	2.49076	2.49078
12. Plastic material & resins	2.34104	2.34104	2.34105	2.34104	2.34105	2.34105	2.34105	2.34107
13. Petroleum refining	2.52091	2.52091	2.52091	2.52091	2.52091	2.52092	2.52092	2.52094
14. Farm machinery	2.30142	2.30142	2.30142	2.30142	2.30142	2.30142	2.30143	2.30144
15. Wholesale trade	1.65036	1.65037	1.65037	1.65036	1.65037	1.65037	1.65038	1.65039
16. Retail trade	1.45258	1.45258	1.45258	1.45258	1.45258	1.45259	1.45259	1.45260
17. Insurance carriers	2.11911	2.11911	2.11911	2.11911	2.11911	2.11912	2.11912	2.11914
18. Real estate	1.65704	1.65706	1.65706	1.65705	1.65706	1.65709	1.65712	1.65723
19. Advertising	2.78320	2.78320	2.78320	2.78320	2.78320	2.78321	2.78321	2.78323
20. All other	1.95463	1.95464	1.95464	1.95464	1.95465	1.95465	1.95465	1.95467

at $117.9 million from the livestock industry. This value represents draft animals and serves as an imputed value for manure used. A discussion with experts led to the conclusion that this is an overestimate and needs adjustment. In input-output analysis, commodities are shown as if moving directly from producer to user, bypassing trade. The output of trade and transportation measures margins, i.e., profits plus operating expenses (*2*). Tobacco is considered to pass directly to stemming and redrying and from the latter to cigarette and cigar manufacturing. However, tobacco has to be aged for about 3 years before being used for manufacturing. A special procedure to allow for this service for storage should be developed.

The use of budget and cost data to extend the input-output table points to a source of data which need to be investigated in greater detail. The Commerce Department table aggregates the agricultural sector into fairly broad categories. For applied policy analysis, an input-output table showing several crops and livestock activities as separate industries is needed. The budget and cost data can be used in setting up such a table.[4] Other suggested uses for budget data are updating the input-output tables, and constructing regional input-output tables.

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[4] Other attempts at extending the input-output table (*5,11*) may also be noted.

An Aggregate U.S. Feed Grain Model*

By Karl D. Meilke

The demand for U.S. feed grain is estimated using a six-equation simultaneous model. Four different utilizations of feed grain and feed grain price as well as the number of animal units fed are estimated. The reduced form of the model is used to provide forecasts of the endogenous variables for the 1973 and 1974 crop years. The structural equations are estimated using two-stage least squares and annual data from 1945 to 1972.

Keywords: Simultaneous equations, demand, model, feed grains, feed concentrates, two-stage least squares, impact analysis.

The feed grain economy is an important sector in U.S. agriculture. Production of the four feed grains—corn, oats, barley, and grain sorghum—contributed $9.0 billion to the $68.8 billion gross farm income in 1972. Likewise, the feed grains were the major input into a livestock sector that produced $35.6 billion of 1972 farm income. Given the importance of the feed grain sector, relatively little research interest has been shown in the demand for feed grains since the early 1950's when a series of U.S. Department of Agriculture studies dealt with the problem (*6*, *12*, *15*). However, events of the 1970's have served to refocus attention on the feed grain sector. First, in 1970, corn blight caused corn production to fall to its lowest level since 1964. Second, record high prices for all grains in 1973 led to the depletion of Government feed grain stocks. Third, the drought-reduced crop of 1974 leaves the United States with its lowest total supply of feed grain since the 1957 crop year. Each of the preceding events has led to concern about the future level of feed grain price and utilization. To provide insight into the feed grain market and to help answer some of the questions being asked, a six-equation simultaneous model of feed grain demand is developed in this paper.

The primary objective of the study is to formulate and estimate a model of feed grain demand that can be used to provide short-run forecasts of the four major utilizations of feed grain, the price of feed grain, and the number of grain-consuming animal units on feed. Improved knowledge of the structure of the feed grain market will enable researchers to study the effects of changes in market structure on the entire system. Examples of the specific type of questions the model can provide answers for are:

(1) What is the effect of a change in the Government loan rate for feed grains?

(2) What is the effect of a bumper feed grain crop with different price support levels?

(3) What would be the effect of eliminating concessional exports?

(4) What is the relationship between changes in personal consumption expenditures, animal units, and feed prices?

(5) What effect would a 10 percent decline in the production of feed grains in major importing countries have on the U.S. feed grain economy?

(6) What is the effect on feed grains of a change in the price of high protein feed?

(7) How are the secondary demands for feed grains affected by price changes?

(8) What is the relationship between feed grain prices and livestock prices?

The Statistical Model: Structural Equations

The feed grain market is represented by a six-equation simultaneous model. The six endogenous variables explained by the model are (1) quantity of feed grain fed, (2) quantity of feed grain used in food and industrial products, (3) quantity of feed grain stored, (4) quantity of feed grain commercially exported, (5) price of feed grain, and (6) number of grain-consuming animal units fed. The structural equations in the model and the variable definitions are given in table 1.

In the econometric model the demand for seed and the import levels are not considered. To preserve the equilibrium conditions, production is adjusted by adding imports and substracting the quantity used for seed. Likewise, the supply of feed grain is not considered in this study.[1] The production of feed grain is taken as predetermined, which implicitly assumes that current feed grain price has no effect on current production.

The structural equations in the model are estimated using two-stage least squares and crop year data from 1945 through 1972.[2] All of the behavioral equations in the system are linear in actual values and overidentified.

*I would like to acknowledge the encouragement and assistance given by Dale C. Dahl and Willis Peterson, Department of Agricultural and Applied Economics, University of Minnesota, and the journal referees.

[1] For examples of work on the supply side see (*10*, *11*, *19*, *20*, *21*).

Table 1. The feed grain model, crop year basis

Behavioral relationships

1. Feed: $QF_t, PF_t, AU_t; PHPF_t, PL_t, e_1$
2. Food and industry: $F_t, PF_t; Y_t, DY_t, WPI_t, DC_t, e_2$
3. Export: $QE_t, PF_t; PHPF_t, CE_t, AUF_t, R_t, SF_t, e_3$
4. Inventory: $S_t, PF_t; PS_t, S{-}1, QG_t, e_4$
5. Animal units fed: $Au_t, PF_t; PF{-}1, PL{-}1, Y_t, AU{-}1, e_5$

Identity

6. $QF_t + QE_t + F_t + S_t + CE_t = S{-}1 + QG_t$

Variable identification

QF_t = quantity of feed grains fed during crop year t. Million tons. (endogenous) (*29, 30*)

PF_t = an index of prices received by farmers for feed grain during crop year t. (1945 = 100) (endogenous) (*29, 30*)

AU_t = number of grain-consuming animal units produced during crop year t. Million units. (endogenous) (*29, 30*)

$PHPF_t$ = an index of wholesale prices of 11 high-protein feeds during crop year t. (1967 = 100) (exogenous) (*29*)

PL_t = an index of prices received by farmers for livestock and livestock products during crop year t. (1910-14 = 100) (exogenous) (*27*)

F_t = quantity of grain used in producing food and industrial products during crop year t. Million tons. (endogenous) (*28, 29, 30*)

Y_t = real personal consumption expenditures during crop year t. Billion dollars. (exogenous) (*26*)

DY_t = a zero-one variable equal to zero for 1945 to 1952 and one for 1953 to 1972 multiplied by real personal consumption expenditures during period t. (exogenous)

QE_t = quantity of feed grains commercially exported during crop year t. Million tons. (endogenous) (*29, 30, 31*)

CE_t = quantity of feed grain exported under PL-480 during crop year$t$. Million tons. (exogenous) (*31*)

R_t = an index of production of feed grain per animal unit in Japan and seven European countries. (1960 = 100) (exogenous) (*25*)

PS_t = an index of the Government loan rate during crop year t. (1945 = 100) (exogenous) (*29, 30*)

$PL{-}1$ = livestock and livestock product prices lagged one year. (1910-14 = 100) (exogenous) (*27*)

$PF{-}1$ = feed grain prices lagged one year. (1945 = 100) (exogenous) (*29, 30*)

DC_t = a zero-one variable equal to zero for 1945 to 1952 and one for 1953 to 1972. (exogenous)

QG_t = quantity of feed grains produced, adjusted for imports and seed use, during crop year t. Million tons. (exogenous) (*29, 30*)

$AU{-}1$ = number of grain-consuming animal units lagged 1 year. Million units. (exogenous) (*29, 30*)

WPI_t = wholesale price index for all commodities during crop year t. (1957-59 = 100) (exogenous) (*26*)

AUF_t = an index of number of animal units fed in Japan and seven European countries. (1960 = 100) (exogenous) (*25*)

SF_t = July 1 stocks of feed grain in three major exporting countries. Million metric tons. (exogenous) (*28*)

S_t = end of crop year carryover stocks of feed grain. Million tons. (endogenous) (*29, 30*)

$S{-}1$ = end of crop year carryover stocks lagged 1 year. Million tons. (exogenous) (*29, 30*)

Livestock Feed

In the equation used to estimate the demand for feed grains to be fed, the price of feed, the quantity of feed fed, and the number of animal units are endogenous variables. The prices of high-protein feed and livestock are considered exogenous.

Livestock prices are almost always treated as exogenous in feed grain models, for two primary reasons. First, as Fox has argued, the supply and consumption of livestock products are nearly predetermined in the short run, and for this reason livestock prices can be treated as exogenous in feed grain models (*8*, p. 101). Second, not treating livestock prices as exogenous results in considerable expansion of the econometric model. Since the prices of different livestock and livestock products are affected by different demand forces, the model would most likely have to be expanded to take explicit account of several different livestock products. Therefore, in this model livestock prices are treated exogenously in order to limit the scope of the study and because it appears the error involved is quite small. In general we would expect the price of livestock to affect feeding rates while the number of animal units fed accounts for the direct demand shifting influence of changes in the number of animals fed.

The treatment of high-protein feed prices as exogenous is a much more important and crucial decision. In King's study of the byproduct feed market, he considered the price of feed grains and the price of protein feed to have been determined simultaneously (*12*, pp. 79-88). King found a strong substitution effect between the feed grains and the protein feeds. Conditions have changed substantially since King's study, which was based on 1921-41 data. In 1941 less than 10 percent of the protein feed fed was soybean meal. By 1970 almost half of the protein feed fed was soybean meal. This has created a completely different market from the one King was analyzing. No longer can we safely assume that the production of protein feed equals the consumption of protein, since exports are extremely important for soybean meal (*9*). King recognized this fact when he stated that to the extent that crushing of soybeans depends on the current price of soybean meal, it is not correct to assume that production of meal is predetermined (*12*, p. 82).

[2] All of the feed grain price and utilization data are based on a crop year defined to be October 1 to September 30 for corn and grain sorghum, and July 1 to June 30 for oats and barley.

If we are to treat high-protein feed prices as exogenous, the relevant criterion is whether feed grain prices or feed grain consumption affects high-protein feed prices. Fox argues that changes in the price of high-protein feeds are relatively independent of changes in the price of feed grains. He argues that much of the correlation between feed grain and high-protein prices is due to the common effect of changes in livestock prices (*7*, p. 69). J. P. Houck in his model of the soybean market does not include feed grain prices in his equation relating to the domestic demand for soybean meal (*9*, p. 17).

Considering the end uses of high-protein feed, it also seems logical to treat the price of high-protein feed as exogenous. When the price of high-protein feed increases, farmers are likely to substitute home-grown feed grain for high-protein feed. On the other hand, the major user of protein feed is the formula feed industry (*14*, pp. 75-76). Therefore a change in the price of feed grain will have little effect on protein feed use because of feed manufacturers' inability to substitute feed grain for protein feed and still maintain a balanced ration.

The statistical estimate of the quantity of feed grains fed is presented below:

$$(1)\quad QF_t = -90.41 - .439\,PF_t + 2.01\,AU_t$$
$$(39.34)\ (.097)\qquad (0.37)$$
$$[-.411]\qquad [1.92]$$

$$+ .157\,PHPF_t + .066\,PL_t$$
$$(.061)\qquad (.053)$$
$$[.14]\qquad [.17]$$

Standard error of estimate = 5.92
$D.W.$ = 1.58
R^2 = .93

The standard error of each variable's coefficient is presented in parentheses and the elasticity at mean values in brackets, below its estimated coefficient.

The signs on all of the variables in equation (1) are correct and the coefficients are large in relation to their standard errors, except for the price of livestock. The independent variables in equation (1) explain 93 percent of the variation in the dependent variable.[3]

The direct price elasticity of −.41 is similar to estimates calculated by Foote and Meinken (*6*, *15*). The elasticity with respect to animal units, 1.92, is also similar to that estimated by Foote when he used quantity of feed grains fed as a dependent variable.[4] The elasticity of feed grains fed with respect to the price of high-protein feed is .14. This is a much lower estimate than the elasticity King found, .63 or .47, depending on the form of the equation, using 1921-41 plus 1946-54 data (*12*, pp. 86-87). It is also lower than the estimate of .41 by Chuang and Judge using 1927-59 data, with 1942-46 omitted (*3*, pp. 15-18). The results of these studies would lead to the conclusion that the cross elasticity between the quantity of feed grains fed and the price of high-protein feeds has been declining since the 1920's. This conclusion seems reasonable given the increased awareness of the nutritional value of protein in animal rations. Farmers are less likely to reduce the quantity of protein in their rations than they were in earlier years.

The elasticity of feed grains fed with respect to current livestock price is estimated to be approximately .17. This is somewhat lower than the elasticities of .39 calculated by King and of .37 by Chuang and Judge (*3*, *12*). The lower livestock price elasticity indicates that farmers have changed their feeding practices in the postwar period. This has implications in regard to the amount of the time that will be required to produce additional livestock products generated by an increase in livestock prices. In particular, high livestock prices are likely to last longer as farmers wait to increase their livestock herd rather than increasing production per animal.

In summary, it appears that the elasticity of feed grains fed with respect to feed grain prices and changes in number of animal units has been quite constant for the past 50 years. The elasticity with respect to high-protein feed prices and livestock prices has fallen since the prewar period.

Food and Industry

Each year approximately 10 percent of the feed grain crop is used to produce products that are consumed either by consumers or in industry. Barley is employed primarily by the alcoholic beverage industry and oats are made into breakfast foods.

Although comprising only about 10 percent of the corn crop, corn used for food accounts for about 80 percent of the feed grains used in food and industry. Corn products are classified as either wet process or dry process products. Dry processed corn products include dry breakfast food, cornmeal, and corn flour. Wet processed products include cornstarch, corn sugar, corn sirup, and corn oil. The production of dry processed corn products has decreased in importance since 1945 when they comprised 50 percent of the total corn products to 30 percent in 1970. The total production of cornmeal has increased slightly since 1945, but has declined on a per capita basis from 17.6 pounds per person to 7.4 pounds per person in 1970. Cornmeal is

[3] Tomek (*24*) has pointed out the difficulty of interpreting R^2 in a 2SLS regression. In equation (1) the residuals are calculated as $\mu_1 = y_1 - Y_1\hat{\alpha}_1 - X_1\hat{\beta}_1$ using Tomek's notation. Therefore R^2 has the range $(-\infty, 1)$.

[4] An elasticity for the animal units variable greater than 1 implies feeding rates increase as the number of animal units fed increases. While an elasticity slightly greater than 1 would appear reasonable, an elasticity close to 2 seems quite high. Most of the past studies of feed grain demand also found a high elasticity for this variable.

generally assumed to have negative income elasticity. The use of corn in wet processed products has increased substantially since 1945. The production of cornstarch has nearly doubled and the production of corn oil has more than doubled in the past 26 years.

The total consumption of feed grains in food and industrial products declined from 1945 until 1953. This decline was due primarily to the reduction in the consumption of corn meal and corn sirup. Since 1954 the increase in the consumption of corn oil, corn hominy, and a shift in the consumption of corn sirup have caused total consumption of all grain products to increase. Due to the change in direction in the total consumption of feed grain products, slope and intercept dummy variables are included in the feed grain consumption function. We would expect the income elasticity in the early years to be negative when it is dominated by the decline in corn meal consumption and to be positive in the later years. The income variable used in the statistical analysis is real personal consumption expenditure, during the crop year. The income variable includes the effect of increases in individual income and population.

We would expect the use of feed grains in food and industrial products to be responsive to changes in business conditions. The wholesale price index of all commodities is used as a proxy for the level of business conditions. If the proxy is fairly accurate, we would expect the use of feed grains for processed products to increase when the wholesale price index rises and to decrease when it declines.[5] In general, we would expect the price elasticity of demand for feed grains used in food and industrial products to be close to zero since grain comprises only a small proportion of the total product costs.[6] The estimated function is

$$(2)\quad F_t = 12.41 - .014\,PF_t - .008\,Y_t + .027\,DY_t + .012\,WPI_t - 7.44\,DC_t$$

(3.05) (.009) (.018) (.016) (.028) (3.78)

[-.13] [-.18]* [.59]** [.10]

Standard error of estimate = .55

$D.W.$ = 1.62

R^2 = .93

*mean of 1945-52

** = mean of 1953-72

All of the variables in equation (2) have the expected signs, but the standard errors for the variables relating to the wholesale price index and real personal consumption expenditures are quite large. This may be due in part to high multicollinearity between these two variables.

The direct price elasticity is very inelastic as was to be expected, although it is somewhat higher than that of −.03 calculated by Brandow for corn (*1*, p. 65). Part of the divergence can be explained by the fact that Brandow did not estimate industrial demand and assumed it to be −.10. The coefficients on the personal consumption variable and the slope dummy variable include the direct demand shifting influences of increasing income and population growth. In 1945-52, the effect of increasing personal consumption expenditures had a negative but statistically insignificant effect on the amount of feed grains utilized in food and industrial products. In the later period the income elasticity is positive, reflecting the increased importance of wet process corn products. The elasticity of feed grain consumption with respect to the wholesale price index of .10 indicates that the use of feed grain is affected by business conditions.

Exports

Since this study is concerned primarily with U.S. agriculture, the influence of foreign developments is introduced into the model with a simple, single equation, export function. If the primary purpose had been to study the feed grain export market, a more detailed model would have had to be constructed. To be realistic, a model concentrating on exports would probably have to include an equation for each major importing and exporting country (*17*, *18*).

The quantity of feed grains exported from the United States is subject to a great number of influences. In particular, it is subject to changes in import duties and quotas in foreign nations. U.S. exports are also affected by development decisions made in foreign countries on whether to be self-sufficient in the production of feed grains, livestock products, or both. Historically, Europe and Japan have been the major importers of U.S. feed grains. To represent conditions in importing countries in the statistical model, an index of feed grain production (expressed in terms of total digestible nutrients) divided by grain-consuming animal units was constructed for Japan and seven European countries.[7] We would expect U.S. exports to increase when the ratio of total digestible nutrients to animal units falls in the major importing countries. An index of the number of animal units in Japan and the seven European countries is also included in the analysis. For countries not self-sufficient in the production of feed grains, we would expect increases in the number of animal units to increase U.S. exports. The July 1 stock of feed grain in three principal

[5] The prices for the various feed grain products are not collected at either the wholesale or retail level. Therefore, it is not possible to include an index of product prices in the consumption function.

[6] This statement is true only under certain conditions which appear to hold in this case. For a discussion of the problem see Bronfenbrenner (*2*).

[7] The seven European countries are Spain, Netherlands, Italy, West Germany, Belgium, Luxembourg, and the United Kingdom.

exporting countries is contained in the export equation.[8] U.S. exports should decline when stocks in the other major exporting countries are high.

With the establishment of the Food for Peace program in 1954, some feed grains are exported under concessional sales programs. The goal of the program is to provide low-cost feed grains to the least developed countries. The concessional export program was planned so as not to displace commercial sales, but is was felt that there may be a spillover effect. If there is, we would anticipate concessional exports of feed grains to reduce commercial exports.

The price of high-protein feed is incorporated in the statistical model to allow for the possibility of importing countries substituting high-protein feeds for feed grains under favorable price conditions. We would expect the direct price elasticity of demand for feed grain exports to be fairly high since importing countries can purchase their grain requirements from other sources. Equation (3) presents the results of estimating the export demand function.

$$(3)\quad QE_t = 22.90 - .137\,PF_t + .172\,PHPF_t - .260\,CE_t$$
$$(11.87)\ (.044)\qquad (.029)\qquad (.471)$$
$$[-1.20]\qquad [1.39]\qquad [-.043]$$

$$- .245\,R_t + .143\,AUF_t - .200\,SF_t$$
$$(.077)\qquad (.054)\qquad (.199)$$
$$[-2.04]\qquad [1.16]\qquad [-.19]$$

Standard error of estimate = 2.67
$D.W.$ = 1.95
R^2 = .93

The direct price elasticity is fairly high, as expected. Brandow, using different techniques, estimated the price elasticity of feed grains for export to be -1.3 in the late 1950's (*1*, p. 55). The model indicates a substitution effect between the feed grains and high-protein feeds. Importers are apparently willing to substitute high-protein feeds for feed grains when feed grain prices are high. The sign on the concessional export variable is negative, indicating that concessional exports may have replaced some commercial sales.

Conditions in Japan and the major importing countries of Europe are important in determining the quantity of U.S. feed grain exported. The elasticity of U.S. exports with respect to a change in the ratio of TDN/animal units in Europe and Japan is -2.04. An increase in the number of animal units fed in the importing countries will also increase U.S. exports approximately 1.16 percent for every 1 percent change in the animal units index, holding R_t constant.

[8] The three major countries exporting feed grains are Canada, Argentina, and Australia.

Inventory

The end-of-year carryover of feed grain supplies is held by farmers, commercial grain traders, and the Government. Since 1945 the role of the Government in storing feed grain has varied greatly. Under the provisions of the farm price support program a participating farmer may obtain a loan from the Commodity Credit Corporation (CCC) using his grain as collateral. The farmer may repay the loan by delivery of his feed grain to the CCC or by repaying the loan plus carrying charges.

The stock of Government-stored feed grain increased rapidly from zero in 1947 to a peak of 74.7 million tons in 1960. After 1960, tightened production controls and lower loan rates resulted in smaller Government carryovers. By the end of the 1974 crop year stocks held by the Government will be negligible.

The quantity of feed grain accumulated in Government stocks is largely determined by the relation between market prices and loan rates. When market prices are high relative to loan rates, the Government inventory declines; conversely, Government inventories increase during periods of high loan rates and low market prices.

The commercial inventory of feed grain is held in farm storage facilities, country elevators, terminal markets, and warehouses to provide working stocks for the milling industry, formula feed industry, and exports. Over the study period the share of total carryover held by commercial interests varied from 12 to 100 percent.

Although it would seem preferable to estimate separate demand functions for commercial and Government stocks, only one combined inventory function is used in the model. This approach is taken because of the tendency for a linear Government inventory function to predict negative inventory levels during the recent period of very high prices. In general little predictive ability is lost by using the single stock function.[9]

In the statistical model the end-of-year carryover is assumed to be a function of feed grain price, Government loan rate, total production, and inventory lagged 1 year.[10] High feed grain prices indicate limited supplies and a high cost of holding inventories; therefore, we would expect year-end holdings to decline when prices have been high. The Government loan rate represents the Government's willingness to purchase grain. In years of high loan rates, farmers will tend to sell their grain to the Government rather than feeding it or selling it in the open market. Generally some fraction of total production is necessary to provide pipeline or working stocks. This influence is taken into account by including total production in the inventory equation.

[9] For an example of separate Government and commercial inventory equations see (*14*).

[10] The theoretical arguments for this type of specification are presented in (*13*, *11*, pp. 80-81).

Since feed grain can be stored over long periods of time and the CCC is unable to sell grain at will, a lagged stock variable is also included in the model.

Equation (4) explains the demand for carryover stocks.

$$(4)\quad S_t = 20.48 - .436\,PF_t + .250\,PS_t + .652\,S\text{-}1 + .069\,QG_t$$
$$(24.73)\ (.108)\qquad (.102)\qquad (.093)\qquad (.070)$$
$$[-1.04]\qquad [.71]\qquad [.22]$$

Standard error of estimate = 7.47
$D.W.$ = 1.51
R^2 = .88

The estimated inventory demand equation indicates that a feed grain price increase of 1 percent results in a 1.04 percent decrease in the end-of-year carryover. Similarly, a 1 percent increase in the Government loan rate results in a .71 percent increase in the level of carryout.[11]

Animal Units Fed

Animal units enter a derived demand function for feed in much the same was as population enters a consumption function. The basic difference is that the number of animal units a farmer produces is a decision variable under his control. Therefore, in the statistical model the number of animal units fed during a year is treated as an endogenous variable.

In general, the same factors that affect the number of animal units fed also affect the quantities of feed fed per animal unit, although with different time lags. The decision as to how many animal units a farmer will produce is assumed to be made on the basis of current and 1-year-lagged feed grain and livestock prices. Real personal consumption expenditure is included in the animal units equation to reflect the general demand conditions in the economy. The number of animal units produced lagged 1 year is also included in equation (5) since the increase or decrease in animal units produced from one year to the next will depend to a certain extent on the amount produced in the last period.

We would expect positive coefficients on the personal consumption expenditure, livestock price, and lagged animal units variables, and negative coefficients for the feed price variables.

$$(5)\quad AU_t = 49.11 - .066\,PF_t - .031\,PF\text{-}1 + .041\,PL\text{-}1 + .014\,Y_t + .484\,AU\text{-}1$$
$$(12.91)\ (.026)\qquad (.029)\qquad (.016)\qquad (.007)\qquad (.134)$$
$$[-.065]\qquad [-.030]\qquad [.106]\qquad [.044]$$

Standard error of the estimate = 1.83
$D.W.$ = 1.90
R^2 = .91

All of the variables in the equation have the correct signs and 91 percent of the variation in the dependent variable is explained. Farmers appear to respond more quickly to changes in feed price than to livestock price as indicated by the statistically significant coefficient on the current price of feed grain. The current price of livestock was also included as a variable in equation (5) but its estimated coefficient was very small and statistically insignificant, so it was dropped from the final equation. The elasticities calculated by Foote for lagged livestock and feed grain prices for the prewar period are somewhat larger than the ones obtained here (*6*).

General Comments

The structural equations estimated appear reasonable. All of the variables have the expected signs and most of the variable coefficients are statistically significant at a 5 percent level of significance. Serial correlation does not appear to be a problem in any of the structural equations (*4*). Likewise, multicollinearity among independent variables included in any single equation is minimal with the expection of the wholesale price index and real personal consumption expenditures in equation (2). Consequently, the structural equations are used in the next section to provide forecasts of the endogenous variables.

Reduced Form Equations

To use the feed grain model for policy analysis, the reduced form of the simultaneous model is derived. The reduced form of the model expresses each of the endogenous variables as a linear function of all the predetermined variables. The coefficients of the solved reduced form equations preserve all of the behavioral relationships and identities that are built into the structure. For example, any change in the supply of feed grain will be apportioned completely among the four market outlets. In general, the reduced form equations show the equilibrium impact of a change in any exogenous variables on each endogenous variable, while maintaining the relationships among variables implicit in the structure (*32*, p. 161). For this reason the reduced form coefficients are often referred to as impact or short-run multipliers.

[11] Note that the Durbin-Watson test for serial correlation is biased when a lagged dependent variable is included in the equation (*16*). For an alternative test see (*5*).

Table 2 contains the reduced form coefficients for each of the six equations in the simultaneous model. Each endogenous variable is expressed as a function of the 17 exogenous variables in the system. To check the predictive ability of the reduced form equations, Theil's inequality coefficients are calculated for each equation (table 3)[12] (*23*, pp. 15-36). If the inequality coefficient equals zero then the forecast values are equal to the actual values, while an inequality coefficient equal to one implies that the prediction procedure leads to the same error as no-change extrapolation. Table 3 indicates that the inequality coefficients for all of the equations are quite small. Furthermore, Theil has shown that the inequality coefficient is made up of three components: that due to bias, that due to the difference of the regression coefficient from unity, and that due to residual variation.[13] Table 3 reveals that most of the error made in the reduced form predictions of the endogenous variables is due to residual variance. Each of the reduced form equations performs well during the time period used to estimate the structural equations and will hopefully provide good forecasts in the future.

[12] The actual values of the lagged endogenous variables are used in calculating the predicted values. The formula for the inequality coefficient is

$$U = \sqrt{\frac{\Sigma (P_i - A_i)^2}{\Sigma A_i^2}}$$

where P_i = predicted values and A_i = actual values.

[13] The regression coefficient under consideration is the one obtained by regressing A_i on P_i. For a discussion of the decomposition of the inequality coefficient see (*23*, pp. 29-36).

Table 2. Reduced form of the simultaneous system

Endogenous variables	Constant	Predetermined variables							
		$AU-1$	$S-1$	$PF-1$	$PL-1$	Y_t	DY_t	DC_t	WPI_t
AU_t	45.4576	.4285	.0198	-.0277	.0365	.0129	-.0015	.4239	-.0007
QF_t	-23.2888	.4930	.1718	-.0319	.0420	.0183	-.0134	3.6721	-.0060
F_t	11.6412	-.0117	.0042	.0007	-.0010	-.0084	.0269	-7.3519	.0120
S_t	-3.6659	-.3662	.7828	.0237	-.0312	-.0075	-.0102	2.7999	-.0046
QE_t	15.3136	-.1151	.0411	.0074	-.0098	-.0024	-.0032	.8800	-.0014
PF_t	55.3965	.8402	-.3006	-.0544	.0716	.0173	.0235	-6.4235	.0105
		PL_t	$PHPF_t$	PS_t	R_t	AUG_t	SF_t	CE_t	QG_t
AU_t		-.0038	-.0187	-.0142	.0139	-.0081	.0114	-.0421	.0530
QF_t		.0335	-.0051	-.1233	.1212	-.0705	.0989	-.3648	.4592
F_t		-.0008	-.0039	-.0030	.0029	-.0017	.0024	-.0089	.0112
S_t		-.0249	-.1238	.1559	.0924	-.0538	.0754	-.2782	.4196
QE_t		-.0078	.1329	-.0296	-.2165	.1261	-.1767	-.3480	.1100
PF_t		.0571	.2840	.2158	-.2119	.1234	-.1730	.6382	-.8032

Table 3. Theil inequality coefficients for the reduced form equations, 1945-72

Variable	Inequality coefficient	RMS	Percent of error due to:		
			Bias	Regression coefficient different from one*	Residual variance
AU_t	.0084	1.78	Neg.	Neg.	.998
QF_t	.0176	3.99	Neg.	.01	.988
F_t	.0200	.47	Neg.	Neg.	.999
S_t	.0471	4.48	Neg.	Neg.	.999
QE_t	.0736	2.18	Neg.	.001	.998
PF_t	.0392	8.32	Neg.	.09	.906

Neg. - less than .001.

RMS - root-mean-square prediction error.

*Regression coefficient obtained by regressing the actual values on the predicted values.

The solved reduced form equations of the model can be used to examine the impact of selected changes in the predetermined variables on the jointly determined variables. For example, the effect of an increase of 50 million tons in the supply of feed grains can be found by multiplying the figures in table 2 under QG_t by 50. The effect of a 50-million-ton increase in supply is to increase the amount fed to livestock by 23.0 million tons, exports by 5.5 million tons, inventory by 21.0 million tons, and use in food and industry by .5 million tons. The model predicts a 40.2 percentage point decline in the feed grain price index. Additional examples of the impact on jointly determined variables of changing predetermined variables can be obtained by using the reduced form coefficients contained table 2.

Projections

In this section the reduced form equations are used to project the value of the dependent variables for the 1973 and 1974 crop years. By inserting known values for the predetermined variables into the simultaneous model, the system of equations can be solved to forecast the values of the unknowns. Although the exogenous variables in the model are considered to be "knowns," not all of their values are known with certainty at this time. Some economic variables move so slowly along secular trends that their future values can be projected with considerable accuracy; others, such as livestock prices, are subject to more fluctuation (*22*). The values of the predetermined variables used in the feed grain model to project price and utilization rates for 1973 and 1974 are shown in table 4.

Four variables—real personal consumption expenditure, the wholesale price index, foreign feed grain production divided by livestock production, and the index of foreign animal units—are estimated by projecting trends and using outlook information where it is available.[14] The projected production of feed grain is based on farmers' planting intentions.[15] The index of price support loan rates is calculated from announced support levels. Concessional exports and the stock of feed grain in major exporting countries are assumed to remain at their recent average of about 1.5 and 15.0 million tons per year. The high-protein feed price index and the prices of livestock and livestock products are assumed to fall slightly from their 1973 levels in 1974. The values of the lagged endogenous variables are taken from the May 1974 issue of *Feed Situation*.

Table 5 presents the results of using the model to predict feed grain utilization and price in 1973 and 1974. The projected utilizations in 1973 are all quite close to their actual values. The largest error is for commercial exports where the prediction error is 5.7 percent.

The model underestimated the feed grain price level in 1973. This is not surprising, but the size of the error—almost 30 percent—is disturbing. One of the reasons for the model's underestimation of price is the decline of 52 points in the price of high-protein feed between 1972 and 1973. Table 2 indicates that a decline of this magnitude in the price of protein feed should have caused the feed grain price index to decrease 15 points, which it obviously didn't do. The model's projections for 1974 are interesting nevertheless,

[14] Values of the predetermined variables for 1973 are based on data available in July 1974. Consequently the actual values of the predetermined variables for 1973 should be quite close to those in table 4.

[15] If this model is to be used to forecast more than 1 year in advance, production estimates will have to come from other sources. Work is currently under way in the Department of Agricultural Economics, University of Minnesota, to develop supply models that could be used in conjunction with this model for longer range forecasts (*10, 11, 19, 20, 21*).

Table 4. Projected values of predetermined variables used in projection exercises, 1973 and 1974

Variable	Units	Projected value	
		1973	1974
Y_t	Billion 1958 dollars	55.6	560.6
$PHPF_t$	Percent	220.0	216.0
PL_t	Percent	490.0	475.0
PS_t	Percent	105.7	110.0
CE_t	Million tons	1.5	1.5
WPI_t	Percent	155.3	170.8
R_t	Percent	83.0	95.0
QG_t	Million tons	202.0	172.0
AUF_t	Percent	138.0	139.0
FS_t	Million metric tons	15.0	15.0
S-1	Million tons	32.4	22.6
AU-1	Million units	115.4	114.2
PF-1	Percent	129.6	191.0
PL-1	Percent	465.2	490.0

Table 5. Projected values of the jointly determined variables for 1973 and 1974

Variables	Units	1973		Percentage error	1974	
		Actual*	Predicted		Unconstrained	Constrained[1]
QF_t = Feed grain fed	Mil. tons	155.9	156.3	0.3	139.6	134.2
PF_t = Feed grain price	Percent	191.0	135.6	28.6	157.0	164.9
AU_t = Animal units fed	Mil. units	114.2	119.0	4.2	116.1	115.5
S_t = Inventory	Mil. tons	22.6	22.3	1.3	6.2	12.0
F_t = Food and industry	Mil. tons	15.1	15.6	3.3	15.5	15.5
QE_t = Exports	Mil. tons	41!9	39.5	5.7	33.1	32.0

*Preliminary, based on data in *Feed Situation*, May 1974.

[1] These values are obtained by restricting the 1974 carryout (inventory) to equal 12.0 million tons.

especially when compared with the model's 1973 forecast.

The model's unconstrained forecasts for 1974 indicate an end-of-year carryover of only 6.2 million tons. Under this condition grain prices are predicted to increase about 16 percent over the model's predicted price in 1973. A grain carryover of 6.2 million tons seems rather unrealistic, since more grain than this is probably needed simply to provide pipeline stocks. Consequently the model was rerun, using 12.0 million tons as an estimate of the minimum carryover stocks needed in 1974. These results are given in the last column of table 5. With the 1974 carryover constrained to equal 12.0 million tons, the model predicts prices 21.6 percent higher than in 1973. Even at these higher prices, 32.0 million tons of feed grain are exported. Feed grains fed are predicted by the model to fall to 134.2 million tons which would be the lowest level of feeding since 1968. (USDA projections in November 1974 indicated less than 127 million tons might be fed.) The 1974 feed grain price projections by the model probably represent a lower bound for actual price changes because of the assumption that high-protein and livestock prices will decline slightly in 1974. Any substantial increase in either of these variables would lead to higher feed grain prices than predicted above.

Summary

The six-equation simultaneous feed grain model appears to be a useful tool for predicting future levels of feed grain utilization and price. The model also provides a framework within which the effects of changes in specific variables on the entire system can be evaluated.

Future work should be concentrated in two areas: (1) some of the more volatile exogenous variables, primarily high-protein feed prices and livestock prices, should be made endogenous to the system to make the model less dependent on outside information for short-run forecasts; and (2) a supply model should be incorporated with the demand model to make long-run projections.

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BOOK REVIEWS

Attacking Rural Poverty: How Nonformal Education Can Help

By Philip H. Coombs and Manzoor Ahmed. The Johns Hopkins University Press, Baltimore, Md. 21218. 254 pages. 1974. $15.

This research report on rural learning systems in less developed countries was prepared for the World Bank by the International Council for Educational Development. Twenty-five nonformal education programs in 15 countries of Africa, Asia, and Latin America were studied in depth and a large number of additional programs were examined in a more cursory manner. The authors define nonformal education as "any organized systematic educational activity carried on outside the framework of the formal system to provide selected types of learning to particular sub-groups of the population..." Thus every agency which carries a program to rural people would have a nonformal educational component. The authors found that such programs were fragmented, myopic in their conceptions of their missions, frequently competing with one another for scarce resources, unresponsive to local needs, and oblivious of existing local social organization. They were staffed with urban-oriented academic types who were as foreign to the local rural culture as the expatriate technical assistance experts who were supposed to help them.

The authors found a few programs that demonstrated higher cost-effectiveness than most. These programs had linkages with related development and educational activities, both horizontally at the field level and vertically to higher echelons for nourishment and backstopping.

The authors call for greater decentralization and greater equity in programs to help rural people. These can be achieved through the mobilization of existing resources, including rural people, less sophisticated technologies, and institutions already enjoying support from the local community and tied to local employment opportunities. To try to separate system and sector would slow educational progress and cripple its potential.

If the recommendations of Coombs and Ahmed are followed by the World Bank and other lending agencies, a new set of criteria will be applied to feasibility studies, project preparation, and evaluation. A new breed of implementers will have to be found who combine the vision of a generalist and the empathy of a brother with required technical competence (not necessarily achieved through formal education).

Jane M. Porter

In the Human Interest

By Lester Brown. W. W. Norton and Company, Inc. 558 Fifth Avenue, New York 10003. 190 pages. 1974. $6.95.

It seems that the world is becoming increasingly aware that the ominous prophecy of Thomas Malthus could become a reality. The author of this book believes that whether the catastrophe will come about will depend on events within the next 10 years.

Lester Brown, who was formerly with USDA and is currently a Senior Fellow at the Overseas Development Council, predicts that in the near future the demand for food will exceed the world's capacity to produce the necessary amount. He attributes the impending predicament to the rich countries—particularly the United States—which use a large proportion of agricultural resources relative to the rest of the world. For example, to satisfy its material standard of living, this country needs nearly five times as much resources as are required to support India, Nigeria, or Colombia.

The author is sounding a call to avoid the crisis. What is needed to offset the gloomy trend is greater investment in tropical agriculture, irrigation, and better ways to distribute fuel and fertilizer.

Unfortunately, even if food production reaches a level surpassing demand, it may only be temporary. Distribution is likely to be misallocated, since the rich countries would be having surpluses and the poor countries would be having corresponding deficits. If this happens, the author believes that the 1980's will experience international trade problems of unmanageable proportions.

The crucial point in the author's strategy is to have the world population stabilized at a universal birthrate of 24 births per 1,000 persons by 1985, or a total of just under 6 billion people by the 21st century. Our planet cannot support more than that number without a serious curtailment of overall living standards.

In the past the call for the most efficient solution to balance supply and demand was to increase supply. What is now realized is that increasing supply is more difficult than curtailing demand. To facilitate any program to balance supply and demand, society must improve education and health care, income distribution, and full employment. According to Brown, the cost to achieve this would not be as staggering as one might imagine. The cost would be less than $6 billion a year over the next 5 years—a price tag that is easily within the reach of the international community.

The author says little about objections to his plans, and there are a few. The developing countries do not go along with the "population programs"; indeed, as

witnessed from the speeches given by developing countries' delegates at the population conference recently held in Bucharest, the poorer countries do not even recognize that there is a population problem at all. Furthermore, the author has placed too much reliance on the prospect of achieving a "new social ethic"—a radical change in the norms and attitudes of the diverse peoples of the world. It seems certain that even if the changes could occur they will take longer than the short time the author plans.

Nevertheless, Brown's book points out the need for reform of the world's food policy as a necessary condition for stabilizing population, and the consequences if nothing is done.

Jack Ben-Rubin

Dansk Landbrug I 1985? [Danish Agriculture in 1985?]

By Frede Anderson, Hans P. Hansen, Poul Pilgarrd, and Poul Erik Stryg. The Royal Veterinary and Agricultural College, Copenhagen. 384 pages. 1973. (Danish.)

In view of the instabilities which have afflicted the international agricultural economic community in recent years, forecasts of agricultural developments have been subjected to merciless attack by some agricultural economists who are bound by precise mathematical ground rules. Fortunately, the skilled researchers at Copenhagen's Economic Institute of the Royal Veterinary and Agricultural College in Copenhagen courageously published a needed, comprehensive projection study at this time—during the second year of Denmark's transition period as a member of the European Community (EC)—when unforeseen developments in both world prices of inputs and commodities and the supply and demand situation in the EC could have resulted in the delaying of good research, postponed by the common "let's wait and see" rationalization. These uncertainties are probably obvious to the authors, who have titled the report in the form of a question.

However, the value of this study lies not only with the projections, but with the historic data as well. The analysis is divided into two 15-year periods, each subdivided into five sections. These consist of an analysis period (designated A1 to A5, 1956-70, and based on historic data), and a forecast period (P1 to P5,1971-85). The country was geographically divided into 11 producing regions, and within each region all farms have been classified into four production groups. Thus, the researcher, exporter, or farm manager has a wide variety of data for a multiplicity of decisions—data pertaining to a specific crop or livestock product are available by farm sizes and regions for either of the two 15-year periods.

According to the definition provided, "The main objective of the present study has been to analyze the resource use, production pattern, and marketing structure of Danish agriculture and on this basis to make forecasts of regional development in farm size, resource utilization, and production pattern up to 1985."

Some of the major assumptions applying to the projections are that (a) trends in technical and biological improvements affecting agriculture will continue; (b) prices of the factors of production during the projection period will trend upward at the average rate of increase in the analysis period (A1 to A5); (c) price projections are based on EC prices using a base 1968-72 period; (d) an increase in real per capita income is 3.2 percent annually.

Mathematically oriented economists will find the complex, highly technical recursive linear programming model as well as other models challenging. The recursive model employed is a multiperiod model which links individual subperiod models. Consequently, the model is, in this sense, a dynamic one. The model is constructed with the possibility of being linked to further studies, an important factor particularly if international price abnormalities in 1973/74 persist. In addition to production projections, the study provides extensive period analysis relating to agricultural incomes and use of agricultural inputs.

Some of the major conclusions of particular interest to those interested in practical developments in West European agriculture may be cited:

The model projects a continuation of a long range downtrend in the number of farms during the subperiod 1970/71-1972/73 through 1982/83-1984/85, from 134,000 to 89,000, with the decline most pronounced near urban and industrial centers where alternative opportunities are prevalent. Capital and labor scarcity are also important factors related to the farm sector. For field crops, area sown to barley, by far the most important grain, normally accounting for over 70 percent of total grain area, is projected to decline insignificantly by 1985 but will continue to be an important hog feed. Area sown to rye, oats, and grass crops is also projected to decline, while wheat shows a sharp increase in area.

The results applying to livestock and livestock products are especially important to U.S. interests since soybean meal is an important feed in the Danish hog industry, and the meal is largely crushed from U.S. soybeans. Soybeans represent the most important single commodity exported by the United States to Denmark. The projections indicate a strong increase in numbers of fatted hogs throughout the projection period, with a tapering of the rate of increase during the final subperiod. Broiler numbers are projected to increase as well. These results apparently are consistent with previous studies which forecast a rise in animal production reflecting, at the time, higher EC prices. Cow numbers are projected to continue a downtrend.

This comprehensive study, in this reviewer's opinion, should most appropriately be used by readers familiar with highly sophisticated econometric techniques.

Although there is a short English summary, the text is in Danish, which could limit total comprehension to an audience of 5 million! Nevertheless, researchers can weave through the tables with the assistance of a good dictionary.

Marshall H. Cohen

Praeger Library of U.S. Government Departments and Agencies, Praeger Publishers, Inc., 111 Fourth Avenue, New York 10003:

The Library of Congress

By Charles A. Goodrum. 292 pages. 1974. $10.

The Department of Labor

By Jonathan Grossman. 309 pages. 1973. $10.

The National Labor Relations Board

By Frank W. McCullock and Tim Borstein. 200 pages. 1974. $10.

The Office of Territorial Affairs

By Ruth G. VanCleve. 226 pages. 1974. $10.

The Atomic Energy Commission

By Corbin Allardice and Edward R. Trapnell. 236 pages. 1974. $10.

The authors of these studies have had firsthand experience in the agencies about which they are writing. Charles Goodrum was Assistant Director of Congressional Research of the Library of Congress; Jonathan Grossman is historian of the Department of Labor; Frank McCulloch was Chairman of the National Labor Relations Board from 1961 to 1970 and Tim Bornstein was his special assistant from 1969 to 1970; Ruth G. VanCleve was Director of the Office of Territories from 1964 to 1969; Corbin Allardice was Executive Director of the Joint Congressional Committee on Atomic Energy from 1953 to 1955, and Edward Trapnell was Special Assistant to the General Manager of the Atomic Energy Commission.

While these agencies are not closely allied to the Department of Agriculture and to the field of agricultural economics, all may be related. The Library of Congress, as the largest library in the Western world, plays an important role for professional workers, as well as members of Congress, as a supplement to the National Agricultural Library. Goodrum has described the development of its collection, its service to Congress, the library world, the scholarly world, and the cultural life of the Nation.

The Office of Territorial Affairs has only a 40-year history as a unit within the Department of the Interior, but its roots go back to the Departments of State, War, and Navy. Although agriculture has been important in the life of many of the territories administered by the Federal Government, little attention is given to it in the study by Ruth VanCleve. Moreover, the impact of the sugar and pineapple growers in the history of Hawaii is completely ignored.

Allardice and Trapnell have written an interesting account of the history and current operation of the Atomic Energy Commission. While they mention the fact that scientists are using radiation in solving practical problems in agriculture, they do not give further explanation of research by industry or the Agricultural Research Service of USDA.

Grossman's *Department of Labor* traces the development of the idea of a Department of Labor from 1867 down to the present, with chapters on its current activities. Here again, unfortunately, only passing mention is made of relations with USDA and the agriculture sector of the economy.

The authors of *The National Labor Relations Board* have also followed the pattern of discussing the agency within the bounds of its "industrial bill of rights," with no mention of congressional proposals to include farm labor within the agency's scope or to establish a parallel board for agricultural labor.

Nonetheless, the accounts discuss the historical background of each agency and the present functions and interrelationships. They give an understanding for those who cross agency lines as they study or work in the total Government picture.

Vivian Wiser

Credit Systems for Small-Scale Farmers: Case Histories from Mexico

By Simon Williams and James A. Miller. University of Texas at Austin, Studies in Latin American Business No. 14 (Calvin P. Blair, editor). 260 pages. 1973. $5.

Successful Mexican commercial farmers—whose tomatoes and cucumbers North Americans enjoy eating during the cold winter months—have been able to get private financing, aided by deliberate credit orienting policies of the Central Bank. In contrast, credit has flowed sporadically and inadequately to the masses of small freeholders and ejidatarios (farmers on collective landholdings, the ejidos). This is so in spite of the existence of a complex structure of private banks, usurious money lenders, credit advanced by suppliers of materials needed for production, at least five government farm credit institutions, and philanthropic guarantors of loans.

The Williams-Miller treatise dissects current experience in working within the Mexican credit system. It is basically a casebook which shows (a) how the main public and private institutions work, (b) where and how they have succeeded or failed to increase productivity and farmer income, and (c) the type of catalytic impact

on rural and community development the schemes have had under a variety of crop, market, land tenure, and loan guaranty conditions.

The prime purpose of the book is to identify elements of the Mexican farm credit experience, which could be adapted for transfer to other developing countries. This objective is well achieved in chapter 17, which presents 10 annotated commandments for formulation of workable small-farmer credit systems. Here they are:

1. Before initiation of the actual flow of credit, time and money have to be provided so as to learn how to relate effectively to the people that are to be served.
2. Budgets and management plans must allow for ongoing special training of the field staff.
3. The staff is to be considered as professionals, not missionary do-gooders.
4. Whenever large geographic areas and types of farming are covered, large differences in performance of different parts of the credit institution will have to be expected.
5. Size of funds and sources of renewal credit must be large enough to cover the costs of success.
6. Credit extended for production and marketing practices must be ample enough to allow for adequate profit on investment.
7. Credit systems must provide for close supervision all the way from lending in cash or kind to recovery of principal and interest.
8. The policies guiding management of the credit system should reflect caution towards "self-help," since allowing campesinos prematurely to pursue "their own course"—set by people of far greater sophistication—can be destructive and irresponsible.
9. The amount of credit extended to each client should adequately cover conventional agricultural production inputs and such *personal needs* as food, clothing, medical costs, education, and the multitude of expenses (weddings, funerals, fiestas) which must be met in the culture of Mexico. This type of "consumer credit," often overlooked, is especially crucial in the early years of a credit program when the borrower is not yet able to generate his own savings. Without such consumer credit the peasant cannot readily escape the usurious money lender and his control over the quality of life of the rural poor.
10. Last but not least is the need for the credit system to integrate production and marketing, either within its own capability or by suitable arrangements with other institutions and agencies.

The authors note (p. 253):

> The striking difference between public credit programs and those run by large private agribusinesses of Mexico lies precisely in the area of marketing emphasis. The private programs all result from a need for raw materials, produced under close technical supervision to assure quality and quantity at a price acceptable to both parties. In turn, farmers are attracted into such schemes because they are helped in the effective use of what credit buys and are assured of a market and a profit. Historically, public credit banks have encouraged production without careful regard to marketing follow-up. This negligence has meant widespread losses by the farmer and by the lending institution and also has resulted in cynicism toward repayment of debts and criticism of the effectiveness of the banks.
>
> In Mexico private agribusinesses (primarily in the processed-food industry) with effective production-marketing credit systems have laid themselves open to threat, perhaps inevitable when agrarian reform lies at the heart of political ideology. As small-scale farmers have entered into such private credit programs and have benefitted materially, leaders of farmer organizations have made them aware of other gains not achievable through company activity: the emotional satisfaction of managing their own affairs rather than being locked into a controlled production program on their lands, and an increase in income from more direct participation in the profits of the agribusinesses themselves, even to the point of taking over ownership (see chapter 16). The industry in Mexico has not acted overtly upon the long-range implications of the threat. Naturally, public credit institutions are free of such concerns.

The simplicity of presentation of the 10 commandments is deceiving. They sound like "common sense," a commodity which is hard to come by anywhere in the world. Bankers and concerned citizens, interested in the processes of rural development, should have a copy of this book. At $5 it is among the few remaining bargains in our inflation-ridden economy.

Frank Meissner

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